SECTION 6.0

Engineering and Design Criteria

6.1 Introduction

This design criteria section is intended to provide guidelines for performing detailed engineering and plant design for the Chevron Richmond Refinery Power Plant Replacement Project (PPRP, or the Project) to be located in the City of Richmond, California.

6.1.1 General Plant Description

The plant will consist of one 43-MW net General Electric (GE) Frame 6B® model combustion turbine generator (CTG) with inlet air evaporative cooling operating in combined-cycle.

6.1.2 Codes and Standards

The major design and engineering codes and standards applicable to the Project are shown in Table 6.1-1. The plant design shall be in accordance with the codes and standards in all applicable sections and subsections in the latest editions.

TABLE 6.1-1
Major Design and Engineering Codes and Standards Applicable to the Project

AASHTO	American Association of State Highway Transportation Officials	ICEA	Insulated Cable Engineers Association
ACI	American Concrete Institute	IEEE	Institute of Electrical and Electronic Engineers
AISC	American Institute of Steel Construction	IES	Illuminating Engineering Society
AISI	American Iron and Steel Institute	MSS	Manufacturers Standardization Society Practices
AMCA	Air Moving and Conditioning Association	NEC	National Electrical Code (NFPA No. 70)
ANSI	American National Standards Institute	NEMA	National Electrical Manufacturers Association
ASME	American Society of Mechanical Engineers	NFPA	National Fire Protection Association
ASTM	American Society for Testing and Materials Standards	OSHA	Occupational Safety and Health Administration
AWS	American Welding Society	SSPC	Steel Structures Painting Council
CBC	California Building Code, 2007 edition	UL	Underwriter Laboratories Incorporated
CFR	Code of Federal Regulations, Title 29, Chapter XVII, Part 1910	UPC	Uniform Plumbing Code
CTI	Cooling Tower Institute	USEPA	U.S. Environmental Protection Agency
HI	Hydraulic Institute Standards		

6.1.3 Design Data

Table 6.1-2 summarizes the Project site design elements.

TABLE 6.1-2
Site Design Elements

Element	Data
Location:	City of Richmond, California
Elevation above sea level (ft):	15
Design Temperature Range (°F):	32 to 102
Extreme Temperature Range (°F):	15 to 115
Average Annual Temperature (°F):	67
Relative Humidity Range (%):	10 to 100
Average Annual Rainfall (inches):	11.95
Maximum Rainfall 24 Hours (inches):	2.50
Design Wind Speed (mph):	70 mph Basic Wind Speed per CBC 2007
Seismic Design (CBC Zone):	4
Average Equipment Noise Level 3 feet from the outline of equipment:	85 dBA
Noise Level Outside Plant Property Line:	70 dBA (Max.)
Plant Design Life (years):	30

The following is a discussion of engineering design criteria for select subsystems.

6.1.3.1 Heating, Ventilating, and Air-Conditioning Systems

The electrical buildings will include the electrical switchgear room, electronics room, and battery room. The electrical buildings will be provided with heating, ventilating, and air-conditioning (HVAC) systems as necessary for equipment protection and personnel comfort.

6.1.3.2 Piping

Piping Codes and Standards

All process piping will be designed and constructed in accordance with the American National Standards Institute (ANSI) B31.1 Power Piping Code and ANSI B31.3 Chemical Plant and Petroleum Refinery Piping Code. Fire protection piping will be designed, constructed, and installed in accordance with applicable National Fire Protection Association (NFPA) standards.

Piping Material and Design

Piping materials will be selected on the basis of suitability with the fluids being handled and for the complete range of operating pressures and temperatures expected.

The minimum pressure rating for process piping systems will be ANSI Class 150. Joints for piping 2 inches and smaller will be socket-weld, and joints for 2.5 inches and larger will be butt-weld. Flanged joints will only be used where required to match equipment, control valves, and instrumentation, and to join piping of dissimilar materials or where required for disassembly. Threaded joints will not be used except to match equipment or in galvanized piping such as fire sprinklers.

Instrument air piping and tubing will be stainless steel. Service air piping will be carbon steel.

Non-metallic piping systems will be used where possible for underground portions of low-pressure, low-temperature systems such as plant drains, service and potable water systems, cooling water, and fire protection system. Non-metallic piping used for fire protection service will be listed by Underwriters Laboratories (UL) and/or approved by the Fire Marshal (FM). Underground metallic piping will be suitably protected from corrosion by coating and wrapping and through the use of a passive-type cathodic protection system.

Piping Insulation

Thermal insulation of piping systems for energy conservation will be provided where necessary.

Insulation for personnel protection will meet applicable Occupational Safety and Health Administration (OSHA) requirements for maximum exterior casing temperatures and will be specified for all equipment within personnel access or reach that is not insulated for energy conservation. Maximum temperature of surfaces will not exceed 140°F.

Electric heat tracing will be specified for piping systems or portions of piping systems of 2-inch nominal pipe size and smaller that are exposed to outdoor conditions and could experience loss of service due to freezing, such as:

- Non-drainable small bore water piping
- Small bore water piping that is not in service during normal plant operation
- Instrument-sensing lines

Piping containing glycol/water solution for freeze protection will not be heat traced.

Pipe Supports

Piping design and pipe supports will be designed in accordance with the requirements of ANSI B31.1. Supporting elements will be capable of carrying the sum of all concurrently acting loads such as: pipe and fluid weight, operating loads, wind, seismic, etc., and allow pipe thermal expansion and contraction without causing overstress.

6.1.3.3 Valves

Codes and Standards

Valves will meet the requirements of ANSI B31.1 Power Piping Code. Fire protection valves will be UL-listed and/or FM-approved for fire protection service.

Valve Materials and Design

Valve selection will be based on the required function, material, and pressure rating of the piping system, and the size of the pipe and the piping fluid. Valve type will be selected based on operational and maintenance considerations as well as good engineering practice.

6.2 Instrumentation and Controls

6.2.1 Control System Design

The plant instrumentation and control system will be designed to allow the operators to achieve safe and reliable operation of the power plant. Major equipment monitoring, control, and operation will be provided from the control room, requiring only the use of the existing Honeywell Total Plant Solution (TPS) global user station (GUS) consoles for the plant control system (PCS). Supplemental maintenance and local control will be through a control console and the CTG human-machine interfaces (HMIs) local to the machine. The integration of the various plant systems will be accomplished by the PCS. The PCS will be used for supervisory control and monitoring of major plant components and package systems, such as the CTG, and it will be used for direct control of selective catalytic reduction (SCR) loops and other balance-of-plant equipment and processes.

6.2.1.1 Combustion Turbine Generator/HRSG Controls

The CTG will be provided complete with a vendor-packaged and integrated control system that provides for automatic and manual start-up, synchronizing, loading and unloading, protection, and shutdown of the CTG/Heat Recovery Steam Generator (HRSG) system from the control room.

The CTG control system will accept contact inputs for start, stop, and other operating commands from the PCS to perform all normally required operating functions of the CTG. In addition, a numerical communications link will provide CTG process signals and alarms to the PCS for purposes of monitoring, trending, and archiving critical variables.

The HRSG will consist of an integrated system of control partially provided by the HRSG duct burner supplier (burner management system), and the balance of the control residing in the existing Cogen facility PCS. Remote input/output (I/O) panels will be mounted at the electrical power distribution centers to intertie field-mounted instruments and control devices to the PCS system.

6.2.1.2 Plant Control System

The PCS is an existing distributed control system (DCS)-based control system providing analog and sequential logic control, advanced control computations, data acquisition, operator interface, and numerical interface capabilities. The PCS will provide overall control and operator interface to the generating facility, and will incorporate state-of-the-art digital technology in a redundant DCS-based system. It consists of a real-time functionally distributed computer control system equipped with adequate memory, I/O hardware, termination cabinets, redundant data highway, operator interface consoles, engineering workstation, and peripherals such as printers, mass storage, etc.

Features of the PCS include redundancy of control processors, power supplies, operator stations, printers, and communications. In addition to its control capabilities, the system includes features required for historical data recording, data processing, and report generation.

The PCS includes the following additional features:

- Supervisory interface and monitoring of the combustion turbine generator with direct control of all SCR loops, HRSG, auxiliary loads, and balance of plant motor loads and process loops.
- Visual and audible alarms for abnormal events in a display hierarchy based on criticality of the event, from field instrumentation measurements or software-generated calculations of plant systems, processes, or equipment. Capability to prioritize alarms are included. Alarms will be time-stamped to the nearest second.
- All information within the control system is available on the operator video monitors. Information is transmitted between the PCS control nodes or drops via dual redundant data highways. The highways will use an appropriate medium (coaxial cable, fiber optics, etc.). Both highways are active at all times, providing for a “hot backup” in the event of single failure.
- Each of the operator control stations is capable of performing (at a minimum) the following functions:
  - Configuring and tuning all modules in the system (engineering workstation only).
  - Monitoring the value or status of system points (soft and hard).
  - Auto/manual transfer, set point adjustments, and manual operation of outputs.
  - Alarm indicators with alarm overview and alarm summary.
  - Interactive graphic displays.
  - Control processors are capable of performing both analog (basic and advanced) and digital control functions. Process controllers are configured as one-to-one redundant with automatic transfer to the backup controller in case of controller failure. Each processor is capable of being programmed and modified online. In general, all process information is available to the operator within one second of real time.

6.2.1.3 Plant Instrumentation

Plant instrumentation and control equipment will be of a proven design and chosen to ensure a high level of reliability. When redundant controls are required, completely separate devices with individual sensing taps and isolation capability will be provided.

Transmitters

Electronic “smart” transmitters will be used and have a minimum accuracy of ± 0.1 percent of calibrated span.

Pressure-sensing devices will be provided with adequate valving and test connections for in-line calibration. Manifold valves will be used where practical. These manifolds will contain instrument, test, and where required, equalizing valves. Instrument tubing will be sloped and freeze-protected as required and shown on instrument installation details. All transmitter manifolds shall include calibration taps.

Flow transmitters, in general, will be differential pressure type with square root extraction performed in the DCS.

Primary Flow Elements

Primary flow elements include the following:

- Flow nozzle meter runs will be used where highly accurate flow measurements are required.
- Orifice plates will be provided for other liquid or steam process flow measurements as appropriate.
- Vortex shedding flow meters will be provided where high levels of turn-down in measured range are required.
- Thermal mass flow sensors used for gas or air monitoring where appropriate.
- Specialty sensors/transmitters such as magnetic flow meters, turbine meters, or special stack flow sensors will be used for special application measurements as required.

Thermocouples and Resistance Temperature Detectors

All process thermocouples and resistance temperature detectors (RTDs) are of the 3-wire platinum type with normal resistance of 100 ohms at 0°C.

For high-temperature and metal-temperature measurements, thermocouples would be used. Thermocouples, in general, would be type K or E as appropriate.

Thermowells

Temperature sensors will be equipped with thermowells made of one-piece, solid-bored Type 316 stainless steel design.

Local Indicators

Thermometers will be the bimetallic adjustable angle type with minimum 4.5-inch dials and ±1 percent accuracy. Thermowells are furnished for all thermometer bulbs.

Pressure gauges will be the bourdon tube type with solid front cases, 4.5-inch dials, stainless steel movements, and nylon bearings. Gauges will have 0.5-inch National Pipe Thread (NPT) bottom connections and will be provided with pigtail siphons for steam service, snubbers for pulsating flow, and diaphragm seals for corrosive or severe service. Liquid-filled gauges will be used where there is pipeline vibration.

Tubular gauge glasses will be used for low-pressure applications. Transparent or reflex gauges will be used for high-pressure applications. Mica shield will be used with transparent gauges on steam/condensate service. All gauge glasses will be equipped with gauge valves including a safety ball check.

Temperature, Pressure, Level, and Flow Switches

The use of process switches will be minimized, analog transmitters with signal back to the PCS are preferred.

Control Valves

Control valves used in modulating service will have normal operational range from 30 to 80 percent. Minimum control valve body size will not be less than 50 percent of the upstream pipe size. In general, control valve leakage class will be minimum ANSI B16.104 Class IV. Each control valve will be provided with accessories such as filter regulators, solenoid valves, 4-20 milliampere (mA) position transducers and limit switches as applicable. Control valves will be provided with valve position feedback transducers (4-20 mA).

Pneumatic Operators

Pneumatic piston actuators or diaphragm operators will be provided for air-operated valves. Air operators will function properly on plant air supplied between 80 and 125 pounds per square inch gauge (psig) fluctuating pressure. Air filter-regulators will be provided for each operator.

Instrument Piping and Tubing

Instrument piping and tubing will be installed in accordance with applicable installation details and routed in an orderly manner, grouping together lines wherever practical.

Vents, drains, or traps will be provided at high or low points on impulse lines to vent air or entrained solids which may settle out.

Minimum process piping or tubing size will be 0.5-inch except for connections at instruments, which will be manufacturer’s standard.

6.2.1.4 Programmable Logic Controllers

When PLCs are provided as part of the plant or packaged control systems, controller memories will be battery-protected or be of the non-volatile type. Vendors will provide ladder diagram type documentation for all programmable controller logic. A terminal unit will be provided for entering program changes, storing programs, and loading programs directly into the programmable controller memory. All PLCs supplied shall have PC interface and application software to provide data and program retrieval and manipulation. This PC interface may also be used in lieu of a separate terminal unit for programming the PLC.

6.2.1.5 Control Room

The plant control room is located in the existing Cogen control building. It contains the PCS, the plant fire alarm panel, the continuous emission monitoring system (CEMS) data acquisition system (DAS), and other communications and plant monitoring equipment.

6.3 Basis of Civil and Structural Design

These criteria cover general requirements for civil and structural design including earthwork, drainage and paving, steel and reinforced concrete structures, and miscellaneous yard structures.

6.3.1 Civil Site Work Design

6.3.1.1 General

Civil design will be in accordance with the latest City of Richmond design and specification standards and other applicable codes and standards.

6.3.1.2 Earth Work

Earth work will include clearing, grubbing, and stripping where necessary, excavation of soils for structures and foundations, development of cut and fill slopes, and trenching for a storm drainage system, as required.

Earth work will be designed in accordance with the recommendations given in the site-specific geotechnical report.

6.3.1.3 Grading Design

The area within the Project site will be graded to provide adequate positive drainage.

Finish grades will conform to the minimum drainage gradient standards indicated in Table 6.3-1.

TABLE 6.3-1
Minimum Drainage Gradient Standards

Grading/Drainage Standard	Minimum Gradient
Concrete pavement (sheet flow)	0.5 percent
Gravel covered area	1.0 percent
Lined ditches	0.35 percent
Unlined ditches	0.75 percent
Cut, Earth	1 (vert): 2 (horiz.) max
Fill, Earth	1 (vert): 2 (horiz.) max

6.3.1.4 Oily Water

Oil-contaminated stormwater resulting from equipment leakage, routine equipment maintenance, and oil-contaminated area washdown activities will be directed into an existing Chemical and Petroleum Industry (CPI)-type oil/water separator prior to discharging into holding ponds and channels in preparation for treatment in the plant bio-reactor wastewater treatment system.

6.3.1.5 Underground Utilities Protection

Installation of underground utilities shall be at least 3 feet below finish grade. Where such cover cannot be provided the pipes shall be encased in concrete or pipe sleeves, as necessary.

Underground pipes shall be checked for traffic loads using the Marston formula and with reference to AASHTO "Standard Specifications for Highway Bridges."

6.3.1.6 Road and Pavement

Plant roads shall be a minimum of 20 feet wide with turning radii of 30 feet inside and 50 feet outside and capable of sustaining a 40-ton axle load.

Road shall be crowned or crossed slope with a 2 percent minimum gradient.

Roads, maintenance, and parking area shall be paved with concrete or asphaltic concrete. Concrete thickness and base course requirements will be based on site-specific geotechnical report.

6.3.1.7 Striping and Pavement Markings

All edges of the traveled way shall be defined with painted lines. Roadways shall not have painted centerlines.

6.3.2 Structure Design

6.3.2.1 Material Specification

Table 6.3-2 summarizes the applicable material specifications.

TABLE 6.3-2
Material Specifications

Material	Specification
Anchor Bolts	Standard - ASTM A307 Grade C
	High-Strength – ASTM A325, Type 3 (Hot-dipped galvanized or stainless anchor bolts as required)
Anchor Bolts Sleeves	High Density Polyethylene Plastic
Bolts for Structural	ASTM A325-N or X, Bearing and Shear Type connection or A490-N or X, Bearing and Shear Type Connection High Strength Bolts
Checkered Plate	Galvanized steel with safety tread diamonds ASTM A786
Concrete	Structural Concrete: Minimum compressive strength f’c=4,000 psi at 28 days
	Curbs, sidewalks: Minimum compressive strength f’c=3,000 psi at 28 days
Embedded Steel Plates	Plates shall be A36.
Grating	ASTM A569 — 1-1/4” galvanized, ASTM A123
Grout	Master Builder Embeco 713 non-shrink grout or approved equal
Handrailing	Handrails and posts 1-½” diameter standard pipe posts galvanized with horizontal spacing not greater than 12” per California code.
Ladders	Galvanized steel with 3/4” rungs at 12” On Center (OC) Step off platforms provided at 12’ maximum intervals. When ladder height exceeds 20’ above grade, a cage shall be provided.
Masonry Unit	ASTM C90 Grade N-1
Platforms and Walkways	Minimum widths: Operating and Maintenance Platforms: 3’-6” Walkways: 3’-0” Stairs: 2’-6”
Reinforcing Steel	ASTM A6l5, Grade 60
Steel Pipe or Tubing	ASTM A53, type E or S, Grade B
Rain Water Leaders	Schedule 40 Polyvinyl Chloride (PVC) plastic pipe conforming to ASTM D1785 or equal

TABLE 6.3-2
Material Specifications

Material	Specification
Storm Drain Pipe	Reinforced Concrete Pipe (RCP), ASTM C76, High Density Polyethylene (HDPE), ASTM M294 or F894
Structural Steel	ASTM A36, Grade 36
Welding Electrodes	AWS D1.1, E70XX Electrodes

6.3.2.2 Design Loads

Dead Loads (D)

Dead loads include the weight of framing, roofs, floors, walls, partitions, platforms and all permanent equipment and materials. The vertical and lateral pressures of operating liquids shall also be treated as dead loads.

Floors shall be checked for the actual equipment loads. For permanently attached small equipment, piping, conduits, and cable trays, a minimum of 25 pounds per square foot (psf) shall be added to floors and roofs in the areas containing such appurtenances.

Pipe loads on areas with heavy piping concentrations shall be carefully reviewed to determine the applicable design pipe loads.

Where the piping is to be supported from platforms or walkway beams, actual loads shall be determined and used.

Lateral earth pressures and surcharges will be treated as continuously applied loads in a similar manner as for dead loads.

Live Loads (L)

Live loads include floor area, laydown and equipment handling loads, lateral earth pressure and vehicles. The floor area live load shall be omitted from areas occupied by permanently attached equipment whose weight is specifically included in dead load.

Pipe carrying transient liquids on areas with heavy piping concentrations shall be considered as live in nature and carefully reviewed to determine the applicable design conditions and loads.

Dynamic Loads (E)

Wind loads and earthquake loads shall be treated as transient loads acting along the principal axes of the Project from either direction. Such loadings will be treated in accordance with the accepted methods, design procedures and load case combinations as delineated in the appropriate code provisions.

Impact loads due to maintenance or operational procedures which were carefully determined will be appropriately applied to portions subjected to such load conditions.

Supporting elements for equipment generating vibrational loads will be designed to properly dampen and transmit these loading situations along the appropriate load paths.

Operating Loads (O)

- The operating load "O" is defined as the live load expected to be present when the plant is operating. The "O" loads shall be established in accordance with the layout and mechanical requirements.
- In the laydown areas, the actual weight of the equipment as spread out on the floor shall be considered "O."

Minimum Design Live Loads:

Table 6.3-3 includes minimum live loads to be used in the design.

TABLE 6.3-3
Minimum Live Loads, Design

Load Category	Live Load
General	
Roofs	Per CBC 2007
Offices	50 psf
Assembly and Locker Rooms	100 psf
Laboratories	100 psf
Stairs and Walkways	Per CBC 2007
Railing	50 plf or 200 lbs applied in any direction at top of railing
Platforms and Gratings	100 psf
Grade Floors	250 psf
Surcharge adjacent to plant structures	250 psf
Truck support structures	AASHTO HS20-44
Forklift slab area	Max. wheel load as per vendor information for specific lifting requirements
Special Areas	
Control Room	100 psf
Switchgear Floor	250 psf
Battery Room	250 psf
Steel Grating	100 psf
Raceways, main cable trays	50 psf
Pipeways	Actual load but not less than 45 psf on each deck

Notes:
plf = pounds per linear foot
psf = pounds per square foot

Live Load Reduction:

- No reduction shall be allowed for warehouse storage areas.
- No reduction shall be allowed for slabs, beams, joists and girders, for loads exceeding 100 psf.
- Live load reduction shall be in accordance with the California Building Code (CBC), 2007 edition.

Earth Pressure (Pe)
Earth pressures shall be in accordance with the recommendations from the site-specific geotechnical report.

Groundwater Pressure (Pg)
For structural and buoyancy calculations, the high groundwater table shall be as specified in the geotechnical report.

Wind Loads (W)
All structures shall be designed for wind loading in accordance with CBC 2007.

Seismic Loads (E)
All structures shall be designed in accordance with the CBC 2007.

Thermal Loads (T)
All vessels and exchangers shall be investigated for thermal expansion.

Other thermal loads caused by expansion or contraction due to a change in temperature from the erection condition shall receive proper consideration. Such loads shall include:

- Forces caused by partial or complete anchorage of piping or equipment
- Forces caused by sliding or rolling friction of equipment
- Forces caused by expansion or contraction of the structure

Initial temperature for calculating expansion or contraction in structural design = 70°F.

6.3.2.3 Load Combinations

All structures and foundations shall be designed for the most critical effects resulting from the load combinations as specified in the appropriate code provisions.

Soil Bearing Capacity
All load combinations shall be considered for checking of the soil bearing capacity as determined by the geotechnical reports and investigations.

Concrete Structure
Loads shall be combined in accordance with American Concrete Institute (ACI) 318.

Steel Structure
Loads shall be combined in accordance with Section 1612, CBC 2007.

6.3.2.4 Foundations

Foundations will be designed in accordance with the recommendations contained in the Project geotechnical investigation.

Stability ratio of foundations against overturning shall be at least equal to 1.5 to 1, and sliding shall be at least equal to 1.5 to 1.

Foundations for rotating or reciprocating equipment shall satisfy all manufacturers' requirements for design loads, deflection, and vibration limits.

The bottom of all foundations will extend a minimum of 18 inches below finished grade or as recommended by the Project geotechnical report.

6.3.2.5 Design Methods

Seismic

Seismic design method shall be in accordance with CBC 2007.

Wind

Wind design method shall be in accordance with CBC 2007.

Steel

All structural steel shall be designed in accordance with the American Institute of Steel Construction (AISC) 9th edition "Specification for Design, Fabrication, and Erection Structural Steel for Buildings" using the working-stress method.

Concrete

Reinforced concrete structures, except the water-retaining structures, shall be designed in accordance with ACI Specification 318 using the Strength Design Method.

Water-retaining structures, such as the cooling tower basin and acid/caustic tank secondary containment structures, shall be designed in accordance to the Alternate Design Method (ADM) per ACI 350.

The CTG foundation shall be an independent reinforced concrete mat foundation. The foundation shall be a low-tuned reinforced concrete structure that is structurally designed in conformance with manufacturer's criteria and the following three requirements:

- **Rigidity Requirements:** The relative displacements of the bearing supports shall comply with the relative deflection criteria provided by the machine manufacturer.
- **Dynamic Requirements:** The CTG foundation shall be designed as a low-tuned concrete structure. Natural mode analysis shall be performed to assure that the fundamental vertical and horizontal frequencies of the structure do not fall within the range of the machine operating frequencies as specified by the manufacturer. In addition, the rotor unbalance forcing function, during both normal operating condition accidental condition, shall be applied to ensure that possible vibration of the structure does not result in velocities or accelerations exceeding manufacturer's specifications.
- **Strength Requirements:** The CTG foundation shall be designed to retain structural integrity during all operating and accidental condition loads that might be expected to occur during the life of the plant. The design forces related to earthquake motion or

machine accidental events shall be determined on the basis of energy dissipation in the linear (elastic) range of response.

Bonding at construction joints shall be developed by roughening the surface of the existing concrete using industry-standard methods and keeping the surface wet for at least 2 hours prior to concrete placement. Bonding mortar or other surface treatment of concrete surfaces shall not be used.

Water stops will be used at construction joints where water containment is required (i.e., sumps, cooling tower basins, etc.)

6.3.3 Seismic Design

6.3.3.1 General

Seismic design shall be based upon CBC 2007, Seismic Zone 4 and Occupancy Importance Factor I = 1.0. Other design parameters are specified in the geotechnical report and investigation.

6.3.3.2 Equipment Anchorage and Supporting Structures

All major equipment anchorage and supporting structures shall be designed in accordance with CBC 2007.

6.3.4 Wind Design

6.3.4.1 General

All buildings, structures, and outdoor equipment shall be designed to withstand the effect of wind from any horizontal direction.

Wind design shall be based upon the CBC 2007 with basic wind speed of 70 mph, Exposure C, and Occupancy Importance Factor I = 1.0.

6.4 Electrical

6.4.1 General

This section covers criteria for the design of the electrical auxiliary power systems used in conjunction with the combustion turbine generators and support equipment to be installed in the PPRP and integrated into the PPRP electrical network.

6.4.1.1 Design Considerations

The PPRP includes one natural gas- or liquid petroleum gas (butane)-fired CTG driving a 13.8-kilovolt (kV) synchronous generator and one extraction, condensing steam turbine (STG) driving a 12.47-kV synchronous generator. The output of the CTG is connected to the Refinery 115-kV distribution network through a two-winding 13.8- to 115-kV generator step-up (GSU) transformer. The output of the STG is connected directly to 12.47-kV switchgear in one of the existing Refinery substations.

Power for the cogen electrical auxiliary loads is provided through two 13.8- to 2.4-kV auxiliary transformers, and two 13.8-kV to 480-volt (V) auxiliary transformers each connected at the output of the generator. Each auxiliary transformer will be energized from the 115-kV system through the GSU transformer when the generator circuit breaker is open during start-up and periods when the CTG is not operating. Each of the auxiliary transformers is sized to accommodate all auxiliary system loads associated with the entire cogen train, including common loads. Each 2.4-kV auxiliary transformer is connected to one section of a double-ended 2.4-kV switchgear with a normally open bus-tie breaker, and each 480-V auxiliary transformer is connected to one section of a double-ended 480-V switchgear with normally open bus-tie breaker. Automatic (residual voltage activated) transfer to a live bus section is accomplished in response to loss of voltage on either bus. Synchronized, momentary parallel retransfer of a bus section to the normal source is by operator action only.

For the H_2-STG, auxiliary power will be supplied at 4,160 V by a triple-fed 4,160-V switchgear lineup and at 480 V alternating current (Vac) by a triple-fed 480-V motor control center (MCC) lineup. One feed to the 4,160-V switchgear will be from 12.47-kV Bus #3 via a 12.47-kV to 4,160-V stepdown transformer. The other two feeds will be from the two other 4,160-V busses in the hydrogen plant, each fed by its own separate 12.47-kV to 4,160-V stepdown transformer.

The Bus #3 4,160-V switchgear lineup supplies power to the various 4,160-V motors associated with the STG and cooling tower, via a 4,160-V MCC. The switchgear will have vacuum interrupter circuit breakers for the main incoming feeds.

The 480-V load center transformer will be liquid-filled and supply 480-volt, 3-phase power to one feed of the triple-fed load center and MCC. The transformer will be fed from 4,160-V bus #3. The other two feeds to 480-V bus #3 are from the two other 480-V busses in the hydrogen plant, each fed by their own separate 4,160-V to 480-V stepdown transformers from their respective 4,160-V busses (4,160-V Bus #1 and Bus #2). The Bus #3 480-V MCC lineup also supplies power to the various 480-V motors associated with the STG and cooling tower, via a 480-V MCC.

The complete electrical system is economically designed for reliability of service, safety of personnel and equipment, ease of maintenance and operation, minimum power losses, and mechanical protection. The electrical system includes provision for the addition of future loads, and maximum interchangeability of equipment.

Voltage insulation levels, interrupting and continuous current capacities, circuit protection, and mechanical strengths of all equipment shall be selected and coordinated in accordance with good practice and the requirements of the documents or organizations listed in Section 6.1.2.

Electrical system protective devices (relays, fuses, circuit breakers, etc.) shall be selected and coordinated to ensure that the circuit protective device nearest the point of fault (or high overcurrent) will open first (selective tripping) to minimize equipment damage and disturbances to the remainder of the system.

Selection of electrical equipment, and the installations for its use in hazardous areas, shall be in accordance with requirements of NEC Article 500, other applicable related industry standards, and local fire department regulations.

All electrical equipment used in the design of the PPRP shall be in accordance with the appropriate IEEE, NEMA, ICEA, ANSI, NFPA and other applicable industry standards and Chevron standards.

6.4.1.2 Major Electrical Equipment

Major electrical equipment items for the Cogen 3000 portion of the PPRP include:

- One 13.8-kV to 115-kV GSU transformer
- 15-kV bus duct from the output terminals of the CTG generator to the metal-clad 13.8-kV switchgear
- 13.8-kV metal-clad arc resistant switchgear mounted in a power house
- Two 13.8-kV to 2.4-kV auxiliary transformers
- Two 13.8-kV to 480-V auxiliary transformers
- 2.4-kV indoor metal-clad arc resistant double-ended switchgear
- 480-V indoor metal-clad double-ended switchgear
- 5-kV metal-enclosed non-segregated-phase bus duct
- 600-volt metal-enclosed non-segregated-phase bus duct
- Two 2.4-kV arc-resistant MCCs
- Three 480-volt MCCs
- 120-Vac uninterruptible power supply (UPS) system for critical loads
- 125-volt direct current (Vdc) power distribution system including batteries and battery chargers to supply DC power to the switchgear controls and the 120-Vac UPS

Major electrical equipment items for the H_2-STG portion of the PPRP include:

- 4.16-kV indoor metal-clad double-ended switchgear
- 480-V indoor metal-clad double-ended switchgear
- 12.47-kV to 4.16-kV auxiliary transformer
- 12.47-kV to 480-V auxiliary transformer
- 4.16-kV MCC
- 480-V MCC
- 120-Vac UPS system for critical loads
- 125-Vdc power distribution system including batteries and battery chargers to supply DC power to the switchgear controls and the 120-Vac UPS

6.4.1.3 Area Classification

Hazardous Areas

Hazardous area classifications will be in accordance with the National Electrical Code, Article 500. Classifications in the fuel gas area will follow the recommendations of the American Petroleum Institute (API) Standard No. RP-500A and of the local fire department.

All equipment will be suitable for the area in which it is installed. Hazardous areas will be defined on plant area classification drawings.

Non-Hazardous Locations

The switchgear room (and 125-volt battery area if sealed cell batteries are used) are classified as non-hazardous locations. The interface areas between area classifications are defined on area classification drawings.

6.4.2 Systems

6.4.2.1 Protection System

Protective equipment shall be installed to provide protection against electrical faults and abnormal system conditions. The protection schemes are designed and coordinated so that the protective device nearest to the fault operates first, with backup being provided by the next upstream protective device in the system and subsequent relay stages. Selectivity applies in phase-to-phase and three-phase, as well as to ground faults.

In the event of a fault in a generator, in which its protective zone extends from the neutral end of the windings to the load side of generator breaker, the generator breaker would trip and initiate shutdown of the affected turbine generator. The 115-kV breaker on the switchyard side of the GSU will remain closed so that the plant auxiliaries remain energized for restart.

The GSU transformer is protected from lightning and switching surges by station type, metal oxide station-class surge arresters on the high-voltage terminals. For other problems, this transformer, as well as the auxiliary transformers, are each protected by a pair of microprocessor relays for primary protection and backup protection. The protective relays provide the functions of a differential relay, phase and ground, instantaneous and time overcurrent relays, negative sequence, overtemperature, overvoltage and over- and under-frequency relays.

All motors are protected against faults and overloads. Medium-voltage motors are protected by fuses for high level faults and by microprocessor relays for low level faults and overloads. For motors fed from the 480-volt MCC, overload settings shall be in accordance with guidance of the NEC (approximately 1.15 times full load current). Certain critical motor operated valves are not provided with overload protection in the direction of travel required for safe plant shutdown.

6.4.2.2 Grounding System

The grounding system shall consist of a network of buried, bare, stranded copper cables installed around the perimeter of the station site, the generators, the GSU, auxiliary, transformers, the switchgear buildings and along piperacks to connect to the structural steel. The grounding network shall consist of the underground grounding grid, grounding electrodes, equipment-grounding conductors, crushed rock at grade level and above-grade equipment and structure-grounding connections. A separate, isolated, insulated, high-quality grounding system shall be provided at the control room for instruments and computers only. Equipment located remotely from the main grounding network shall be grounded by means of individual grounding conductors and grounding electrodes.

IEEE Standard 80 will be followed where applicable. Any equipment not directly bolted to a grounded supporting structure is connected to the grounding system. Grounding for components of the station:

- The star point (neutral) of the 115-kV wye-connected windings of the GSU transformers shall be solidly grounded.
- The generator neutral point shall be high-resistance grounded through a distribution type transformer with a resistance-loaded secondary winding. Ground fault current shall be less than 10 amperes (A).
- The star point (neutral) of the low-voltage wye-connected windings of the 13.8-kV to 2.4-kV and 12.47-kV to 4.16-kV auxiliary transformers shall each be grounded through a separate grounding resistor. Ground fault current shall be limited to 10 A.
- The 13.8-kV to 480-V and the 4.16-kV to 480-V auxiliary transformers shall be grounded at the star point (neutral) of the wye-connected secondary windings through a high resistance grounding resistor. Ground fault current shall be limited to 5 A.
- The star point (neutral) of each wye connected winding of lighting and low-voltage power transformers shall be solidly grounded.

A separate insulated, isolated instrument ground bus shall be provided and used only for connecting instrument ground terminals and instrument cable shielding. The instrument grounds of individual panels will be connected to a central point using insulated cable to form the instrument ground bus. The connections shall be made radially and looping shall not be permitted. The instrument ground bus shall be solidly connected to the main plant grounding system at one point only. The rest of the instrument ground bus is isolated from ground. The shields of instrument cables shall be grounded at one end only. Thermocouple cable shields shall be grounded at the thermocouple end. All other cable shields shall be grounded at the control room end.

6.4.2.3 Cathodic Protection

Passive type cathodic protection systems will be used where practical for underground metallic piping or equipment. Insulating flanges will be installed to electrically isolate underground pipes from above-grade grounded piping and structures. Non-metallic piping will be used where possible for the underground piping system to minimize the need for cathodic protection systems.

6.4.2.4 DC and UPS Systems

The 125-Vdc and 120-Vac UPS systems shall be sized to accommodate the requirements of all balance-of-plant systems supporting the generators. The turbine generators are equipped with a 24-volt battery system for their own control and fire protection systems. The 125-volt batteries furnished under these design criteria are sized to accommodate all other normal and emergency DC loads including the 120-Vac UPS. The battery and the batteries for the turbine generator may be installed in a separate battery room. Two battery eliminator type chargers are provided for the 125-volt batteries.

The 125-Vdc and 120-Vac UPS systems shall consist of the following items located in the air-conditioned electrical building areas: a solid state inverter, an automatic static transfer switch, two battery chargers, 125-Vdc switchboard/distribution panel, 120-Vac UPS bypass transformer (regulated type), and 120-Vac UPS distribution panel. These systems shall supply all normal power loads and emergency power necessary for orderly shutdown of the unit and shall maintain emergency power to the control system for a minimum of sixty minutes. The 125-Vdc and 120-Vac UPS systems shall also supply power for instruments and switchgear control. Emergency lighting units are not fed from the station battery.

The 125-Vdc system operates ungrounded. Two-pole circuit breakers or fuses in each pole shall be used throughout. Ground detectors and alarms shall be provided.

6.4.3 Equipment

6.4.3.1 Switchgear, MCC and Battery Locations

The 13.8-kV, 4.16-kV, 2.4-kV and 480-V switchgear and the MCCs shall be centrally located with respect to the loads served. The 13.8-kV breakers will be located in a 13.8-kV power distribution center adjacent to the CTG generator. The remaining switchgear and the MCCs will be located in a separate power distribution center. Areas allocated for switchgear and the MCCs shall be sized in excess of the initial installation requirements. Sufficient space shall be provided for future expansion and maintenance work, including the removal and transportation of circuit breakers. Battery type will be determined later.

If sealed cell battery modules are used, including those furnished with the combustion turbine generator, the battery area does not require a deluge shower. However, an eyewash station is required. The battery area will not require isolation from the switchgear room nor special ventilation.

If wet cell nickel cadmium battery modules are used, the battery area will be isolated from other electrical equipment and adequately ventilated according to equipment requirements and local conditions. Deluge shower and eyewash facilities will also be provided.

Adequate fire detection and extinguishing equipment shall be installed in all equipment areas and made easily accessible.

6.4.3.2 Maintenance Control Stations

In general, process actuation and control devices such as motors, valves, etc., associated with the combustion turbine generator unit shall be operated from the plant control room. Local bypass of turbine and generator controls shall not be permitted. Balance of plant motors and motor operated valves will have locally mounted control stations as described below to facilitate maintenance.

Each motor shall be provided with a “REMOTE-OFF-ON” manual switch lockable in the “REMOTE” and “OFF” positions. The switch shall spring return from the “ON” to the “OFF” position.

Each motor-operated valve shall be provided with a “LOCAL-REMOTE” selector switch, lockable in the “REMOTE” position, and a separate spring-loaded “JOG” switch, spring-return-to-center from the “CLOSE” and “OPEN” positions.

All switches shall be keyed the same. All control stations shall be provided with suitable nameplates showing the equipment service identification.

6.4.3.3 Motors

AC Motors

AC motors shall be sized as follows:

- Motors rated 250 horsepower (hp) and larger shall be rated 4,000 Vac, 3 phase, 60 Hz or 2,300 Vac, depending on supply voltage
- Motors rated 200 hp and smaller shall be rated 460 Vac, 3 phase, 60 Hz
- Motors rated 1/3 hp or less shall be rated 115 Vac, 1 phase, 60 Hz

Motors 250 hp and larger shall be fed from the medium-voltage motor controllers close-coupled to the 4.16-kV switchgear using fuse-protected vacuum type contactors. Motors rated 460 volts and 200 hp or less shall be supplied from combination full-voltage starters assembled in the 480-volt MCCs.

Motor service factors shall be as follows:

- Motors 200 hp and lower, 1.15
- Motors 250 hp and larger, 1.0

Motors shall be sized so that their rating at a service factor of 1.0 is not exceeded at any point on the operating curve of the driven equipment. Motor winding insulation shall be class F with class B temperature rise. Rotor bars and end rings of motors 250 hp and larger shall be copper.

Gear losses, if any, shall be added to driven equipment brake horsepower before motor driver rated horsepower is determined.

Motor winding heaters shall be provided in all motors 25 hp and larger. Motors heater power will be supplied by the motor controller or combination starter control power transformer (CPT). Motor heaters shall be operated at 120 volts, 1 phase, 60 Hz up to 1,650 watts. All heaters shall be rated at twice the operating voltage.

Motors 1,000 hp and larger shall be provided with Bently-Nevada type vibration monitors and core-balance CTs mounted in the main terminal box for motor differential protection. Motors 250 hp and larger shall be equipped with six stator winding resistive temperature detectors (RTDs) – two per phase and two motor bearing RTDs. The RTDs shall be 100 ohm platinum type and shall be wired out to a separate motor terminal box. The RTDs will be used to map and monitor the thermal characteristics of each motor.

DC Motors

120-Vdc rated motors, if required, shall have full voltage or current limit type starting as required. DC motor enclosures shall be designed for the service and area where installed.

Motor winding insulation shall be class F with class B temperature rise. DC motors will be powered from the 125-Vdc power distribution system.

6.4.3.4 Motor Controllers

General

Each motor controller shall be properly selected for short-circuit duty, continuous current, voltage level, starting current, and overload current.

Medium-voltage (4,000 volts) motors shall be fed from 4.16-kV switchgear close-coupled to fuse-protected 5-kV vacuum contactors.

Low-voltage (460 volts) motors shall be fed from 480-volt motor-control-center-mounted combination starters.

Motor Controllers—Medium-Voltage Switchgear

Medium-voltage motor controllers shall have three electronic fuses and vacuum-type NEMA E2 contactors. Each motor controller shall be equipped with a CPT for control power.

Additional contactor auxiliary contacts shall be provided for alarms, interlocks, etc.

Each medium-voltage motor controller shall be equipped with a solid-state multi-function motor-protective relay current transformer for each phase and a window-type zero sequence ground current transformer.

Motor Controllers—480-Volt Motor Control Centers

Three-phase motor starters, rated 480 volts, shall be the combination type, with magnetic contactors and molded-case magnetic trip only air circuit breakers (motor circuit protectors, MCPs) for motors up to 200 hp. Circuit breaker operating handles shall be capable of being locked in the OFF position. Each combination starter shall have an adjustable electronic overload relay with an externally operated manual reset button. The overload range shall be selected according to the motor full-load amperes.

6.4.3.5 Lighting

Lighting will be designed to provide unobstructed illumination in all buildings and along all walkways, in general plant areas, on roadways, and around building perimeters.

Lighting fixtures will be located to provide uniform illumination and ease of relamping and maintenance.

Outdoor light fixtures shall be selected, mounted, and positioned to prevent unnecessary illumination of the night sky, and to avoid light trespass, or light source visibility from adjacent properties.

High pressure sodium fixtures will be used for all outdoor areas and in the combustion turbine room. Except for the turbine room, fluorescent light fixtures will be used in indoor areas. All outdoor lighting will be controlled from a single photocell or from locally mounted switches. Outdoor lighting will be fed at 208 volts. Indoor lighting will be fed at 120 volts.

Lighting wire will be rated 600 volts, type XHHW or XHHW-2.

Lighting shall achieve the following minimum maintained illumination levels:

Outdoor Areas

- General exterior area – 0.5 to 2 foot-candles (fc)
- Roadway and perimeter – 0.5 to 2 fc
- Walkways, stairways and platforms – 5 fc

Indoor Areas

- CTG enclosure – 30 fc
- Switchgear rooms – 30 fc

Emergency lighting will be provided in the electrical building and other areas determined to be critical to the facility. This lighting will consist of wall- or ceiling-mounted dual seal beam (battery pack) fixtures and lighted exit signs, and will be suitable for 90 minutes of operation.

Convenience outlets for 120 Vac shall be located in the process areas to be reached by a 25-foot extension cord. A minimum of six 60-A, 480-volt, 4-pole outdoor outlets shall be strategically positioned around the new facility.

Lighting panel boards will be used for the control of lighting, convenience receptacles, single-phase motors, and other similar loads. Lighting panels will be provided with minimum 20-A plug-in circuit breakers. Each panel will be provided with approximately 20 percent spare breakers. Each lighting panel will be fed from a dedicated 480-208Y/120-volt transformer.

6.4.3.6 Wire and Cable

All current-carrying power and lighting conductors will be sized in accordance with NEC ampacity tables and the following criteria, except where minimum sizes are determined otherwise. Conductors should be stranded to provide flexibility (except AWG 12 and 14 conductors used for power and lighting; thermocouple extension wire; and communication wire). All insulated copper wire is to be annealed in accordance with ASTM B3 and have Class B stranding in accordance with ASTM B8. Bare copper wire is to be softdrawn in accordance with ASTM B3, with Class B stranding in accordance with ASTM B8. Medium-voltage cable conductors can be either concentric-stranded in accordance with ASTM B8 or compact-round-stranded in accordance with ASTM B496. All power, control, and instrument cables shall be flame retardant and cable tray rated:

- 15-kV power cable will be class "B" coated, stranded copper, shielded, 90° C, 133 percent EPR or XLP insulation with overall thermosetting CP or CPE jacket.

- 5-kV power cable will be class "B" coated, stranded copper, shielded, 90° C, 133 percent EPR or XLP insulation with overall thermosetting CP or CPE jacket.

- 600-volt power cable will be class "B" coated, stranded, three-conductor copper with ground, 90° C, XLP or EPR insulation with overall thermosetting XLP or CSPE jacket. Individual conductors will be identified per ICEA Method 4, Table K2, complete with bare ground wire. Cables No. 4/0 AWG and above will be single-conductor.

- 600-volt control cable will be class "B" coated, stranded copper, 90°C, XLP or EPR insulation, multi-conductor, with overall thermosetting XLP or CSPE jacket. Individual conductors will be identified per ICEA Method 1, Table K2.
- 600-volt instrumentation cable will be shielded, class "B" coated, stranded copper, 90°C XLP or EPR insulation with overall thermosetting XLP or CSPE jacket.
- 600-volt thermocouple extension cable will be similar to instrumentation except conductors will be solid alloys per ANSI MC 96.1 (standard limits of error).

Minimum Conductor Size for Mechanical Strength

The recommended minimum conductor size for mechanical strength is as follows:

- Power and lighting (600 V max) – 12 AWG
- Single conductor control (120 V) – 14 AWG
- Single pair or triad for instrument – 16 AWG
- Multi-conductor cable for instrument/control – 18 AWG
- 5 kV - 1/C nonshielded power cable – 8 AWG (min. size available)
- 5 kV - 1/C shielded power cable – 8 AWG (min. size available)
- 15 kV - 1/C shielded power cable – 2 AWG (min. size available)
- Ground loop cable – 2/0 AWG
- Cable from ground loop to MCC, switchgear, transformers, tall stacks/vessels, substation fence and pipeway columns – 2/0 AWG
- Cable from ground loop to large motors, cable trays and enclosures – 4 AWG

Minimum Conductor Size for Short-Circuit Duty

Under short-circuit conditions, the temperature of the conductor rises rapidly. Then, due to thermal characteristics of the insulation, sheath and surrounding materials, it cools slowly after the short-circuit condition is removed. Failure to check the conductor size for short-circuit heating could result in permanent damage to the cable insulation due to disintegration of insulation material. The disintegrating insulation may give off smoke and combustible vapors. These vapors may ignite if sufficiently heated. Also, the cable insulation or sheath may be expanded to produce voids, leading to subsequent failure. This is especially serious in 5-kV and higher-voltage cables.

Minimum conductor sizes for various short-circuit currents and clearing times are shown in Table 79 of IEEE Std 141. The ICEA initial and final conductor temperatures (see ICEA P-32-382) are shown for the various insulations. Table 76 of IEEE Std 141 gives conductor temperatures (maximum operating, maximum overload, and maximum short-circuit current) for various insulated cables. Vendor curves based on ICEA are also available for checking cable fault duty.

6.4.3.7 Cable Routing Criteria

In internal building spaces such as the electrical buildings, cable tray and exposed conduit will generally be used. Partial, or full, false floors below computer, communications, or control rooms may be used. Cable fill will be in accordance with NEC Article 318. Outdoor cabling will be installed in cable tray as well as, in some cases, underground concrete-encased, conduit duct banks between major equipment locations and the electrical buildings. Aboveground raceways will be used at the equipment. All raceways, including cable tray, will be installed in accordance with NEC requirements. All raceways will be separated by voltage and/or system as follows:

- DCS data highway
- Communications
- Fire detection and alarm
- Low level signal (4-20 mA)
- 120-Vac and 125-Vdc Control (less than 20A)
- 480-Vac power, motor space heater power and 125-Vdc power (20A or greater)
- 2.4-kV and 4.16-kV power
- 13.8-kV power

Cables will be identified by cable number at each end of each cable. All control wires will be uniquely identified by color at point of termination.

6.4.3.8 Cable Sizing Criteria

Voltage Drop

Voltage drop criteria are as follows:

- Two percent maximum on feeders and sub-feeders.
- Three percent maximum on 4.16-kV and 2.4-kV feeders from switchgear to motor or transformer load.
- One percent maximum on bus ducts, from transformer to MCCs or switchgear.
- Three percent maximum on 480-volt feeders, from starter to motor.
- Two percent maximum on lighting, instrumentation, and other low-voltage circuits, from 120-Vac bus to distribution panels.
- Three percent average in branch circuits, from panels to load center of circuits, with a maximum of four percent to the most distant outlet.

Ampacity

Feeder cables shall be sized based on the following multiplying factors applied to the full load current:

- All motors 1.25
- All transformers 1.15 (times max FA rating @ 65° C)

The following additional provisions shall also apply:

- The maximum ampacity for any cable shall depend upon the worst case in which the cable is routed (tray, conduit, duct, or direct buried). In addition to ampacity, special requirements such as voltage drop, fault current availability, and environment shall be taken into consideration in sizing of cable.
- Cable ampacities shall be in accordance with National Electrical Code Tables 83—10 and ICEA Publication P46—426.

Short-Circuit Current Criteria

The maximum short-circuit current protection and circuit breaker clearing times normally determines the minimum size cable used for a given load. For circuits with unusually long feeder lengths, voltage drop may be the determining factor.

The maximum allowable conductor temperature after a short circuit (assuming rated conductor temperature prior to the short-circuit) can be 250° C for copper conductors insulated with ethylene propylene rubber and cross-linked polyethylene insulation. The minimum size cable to accommodate a given short-circuit current shall be based on allowable temperature.

Cable shall be large enough to accommodate sufficient fault current to activate protective devices for an end of run fault.

6.4.3.9 Spare Raceways and Cables

Conduits

Where conduits are installed in underground duct banks, 20 percent spare conduits shall be included in each duct bank, minimum two conduits between manholes or major pullboxes.

Where overhead exposed conduits are installed in major groups or banks between two locations, 10 percent spare conduits shall be installed between junction box locations, minimum two conduits.

Cable Trays

Cable trays shall be sized to include 10 percent minimum spare capacity, based on cable fill of circuits routed. Supports for trays shall be designed to accommodate cable trays filled to 40 percent capacity.

Cables

A total of 10 percent spare conductors shall be included in routed control and instrumentation cables, in the form of either spare conductors in individual cables or spare cables, between locations where there are large numbers of terminations.

6.4.3.10 Transformers

Transformer sizing shall be based upon running loads (determined from nameplate ratings) for motors, lighting transformers, and other equipment that will be, or may be, operated under normal conditions (i.e., other than power outage). For load estimation, 1 hp shall be assumed to equal 1 kilovolt-ampere (kVA) for induction motors. Spare motor drivers will normally not be considered part of the running load for the purpose of sizing transformers, except that capacity shall be provided for starting the largest spare motor with all normal motor drivers running. Motor drivers of installations having one motor-driven unit and one turbine-driven unit should be considered part of the running operating load for the purpose of sizing transformers. Transformer capacity, as used here, is the self-cooled rating without fans, at 55°C rise.

In general, power transformers (500 kVA and above) should be supplied with 55°C/65°C temperature rise ratings and provisions for future forced air cooling. A transformer dual-rated with a 55°C/65°C temperature rise is capable of supplying 112 percent of its 55°C kVA rating at the 65°C rise.

Single transformers with secondary ratings of 600 volts or less should be sized so that the initial running load does not exceed 80 percent of the self-cooled 55°C rating.

Individual transformers with secondaries of less than 400 volts should not exceed a rating of 125 kVA, and transformers with secondaries between 400 and 600 volts should not exceed a rating of 750 kVA, without a detailed investigation of the effects of high short-circuit currents on secondary equipment.

A single transformer at 2,400 volts or more should not have an initial running load exceeding 90 percent of its self-cooled 55°C rating.

When sizing transformers for double-ended substations, the running load on both buses shall be calculated; loads should be balanced between the buses. Each transformer should be sized to carry 75 percent of this total running load at self-cooled, 55°C rating. It is recommended that each transformer have dual ratings (55°C/65°C). Therefore, when one transformer is out of service, the remaining transformer will be able to supply 112 percent of its rated kVA, or 84 percent of the total running load, at 65°C. Sixteen percent of the load must be dropped until the other transformer is brought back into service or the transformer may be operated in an overloaded state, if ambient conditions allow overloading without exceeding its 65°C rise rating. It is normally not desirable to drop loads while one transformer is out of service, therefore 55°C/65°C rated transformers with fan cooling or larger sized transformers may be used. For example, a 2,500-kVA, 55°C/65°C, fan-cooled transformer sized to carry 75 percent of the total running load can actually carry 105 percent of the total running load with the fans on, thus giving some leeway for adding load in the future. Engineering judgment and load considerations should be used to decide if fan cooling should be provided for the transformers upon installation.